Research Article

Use of Fossil Bryozoans in Sourcing Lithic Artifacts

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This study reviews the occurrence and potential of bryozoans within lithic artifacts and also sets out a methodology for their use in sourcing and discusses the advantages and disadvantages of this approach. We present case studies from our own research and from the literature on using bryozoans in sourcing archaeological lithic artifacts. Fossil bryozoans of different ages and clades can be effectively used to determine the material source of lithic artifacts from a variety of prehistoric ages. The case studies included in this report span the stratigraphic range of bryozoans from the Ordovician to the Neogene. The bryozoans came from four different orders: trepostome, fenestrate, cyclostome, and cheilostome. The use of these lithic artifacts ranged back to 25 ka. Although the majority of the fossil bryozoans were incidental in the artifacts, the bryozoans were still useful for determining their original source rock. The improved searchable online paleontologic databases allow for more efficient use of fossil bryozoans to constrain the stratigraphic and paleogeographic distribution of source outcrops. Although generally underutilized in sourcing prehistoric lithic artifacts, it is clear that by analyzing bryozoans, an increased understanding of the lithologic nature of these materials could be gained by the archaeological community. © 2014 Wiley Periodicals, Inc.

INTRODUCTION

The source or provenance of a lithic artifact herein refers to its geologic source (*sensu* Rapp & Hill, 2006). It is important to know the original source rock of lithic artifacts or their material components as it assists in constraining the locations and distances of prehistoric trade routes (Andrefsky, 2008; Marra et al., 2013). Perhaps the most famous example of this is determining the source of the Stonehenge sarsens and blue stones (Johnson, 2008; Bevins, Pearce, & Ixer, 2011).

Geoarchaeologists use a variety of paleontologic, lithologic, geochemical, and geophysical parameters to determine the source of lithic artifacts. Methods include both destructive and nondestructive approaches such as petrographic analysis, scanning electron microscopy (i.e., SEM for imaging), X-ray fluorescence (i.e., XRF for determining chemical composition), X-ray diffraction (i.e., XRD for determining mineralogical composition), inductively coupled plasma-mass spectroscopy (i.e., ICP-MS for determining isotopic composition), and laser-induced breakdown spectroscopy (i.e., LIBS for determining elemental composition; Ray, 2007; Colao et al., 2010). Due to wider availability and lower cost, most studies are still often based on petrographic analysis (e.g., Flügel & Flügel, 1997; Dreesen & Dusar, 2004). However several studies focus on, or at least include as part of a wider study, the fossil content of the lithic artifact in an attempt to fully characterize it and determine its source. The key is to choose an approach with sufficient discriminatory ability to distinguish the various possible source localities of the lithic artifact. All approaches fail unless the variation within and between replicate specimens is less than that between possible source formations (Rapp & Hill, 2006).

Sourcing small lithic artifacts is problematic, so spatial variability becomes a problem, especially in flints (Wilson, 2007), one of the best preserved lithic artifact material. Physical properties, color, texture, and fossil content can vary within and between flint samples (West, 2004; Ray, 2007). Lithic resources vary greatly in texture, color, composition, and—if present—fossil content, both laterally and vertically in a single outcrop (Meeks, 2000). This variability makes tracing a lithic artifact back to an exact location of a specific outcrop essentially impossible, but it is often possible to attribute it to a particular stratigraphic formation. This is complicated by secondary sources (e.g., downstream gravel bars and glacial till) being exploited in addition to the primary deposit (i.e., the original exposed bedrock outcrop; Rapp & Hill, 2006).

This study examines the use of bryozoan fossils as the discriminating parameter for two reasons. First, the evolutionary process creates fossil taxa with distinct temporal and geographic distributions. As a result, fossil taxa are often more unique in time and space and thus more useful for sourcing compared to physical or chemical parameters. Second, fossils tend to be relatively unaltered from lithic artifact use so they can be more easily related back to their source rock. For example, Key, Teagle, and Haysom (2010) used the occurrence of Lower Cretaceous bivalves in stone floor pavers in an 18th-century church in Virginia, USA, to determine their source in the Purbeck Limestone Group in Dorset, England. Quinn (2008) applied the same principle to microfossils found in a variety of inorganic artifacts. The use of fossils in the field of thin-section petrography of ceramic materials is becoming more common (Reedy, 2008; Peterson, 2009; Quinn, 2013). Rodríguez-Tovar, Morgado, and Lozano (2010a, 2010b) used ichnofossils in lithic artifacts to source Neolithic and Copper Age cherts back to their geologic formations. Just as with the prehistoric lithic artifacts in this study, fossil bryozoans can be used to determine the source of historic dimension stone (Key & Wyse Jackson, 2014).

The authors searched the literature for examples of bryozoans being used for sourcing lithic artifacts. Other than their own original work included here, examples from the literature are few. One reason is that bryozoans are not as common as other, smaller fossils (e.g., foraminifera) in artifacts (e.g., Quinn, 2008, 2013). Another reason is that bryozoan paleontologists are few. For example, the International Palaeontological Association's (2011) online list includes only 43 bryozoan workers. As a result, the taxonomy and paleobiogeographic distributions of bryozoan species are not as well known as other fossil groups. Therefore, their utility as provenance indicators has historically been limited and underutilized by archaeologists. The lack of workers documenting the stratigraphic distribution of bryozoan species has similarly hampered the earlier promise of bryozoan biostratigraphy (e.g., Merida & Boardman, 1967). Biostratigraphy uses fossils for dating and correlating geological materials. The situation has greatly improved with centralized searchable paleobiogeographic databases (e.g., Paleobiology Database (Alroy, 2000)). The goal of this project is to test the use of bryozoans as provenance indicators using the authors' own research and examples from the literature.

FOSSIL BRYOZOANS AS INTENTIONALLY COLLECTED ARTIFACTS

Fossils have a long record as archaeological artifacts. Oakley (1965, 1975, 1978) and Bassett (1982) reviewed the archaeological record of prehistoric collection of vertebrate and invertebrate fossils starting 33 ka. Mayor (2000) examined the use of fossils by the Greeks and Romans 3.3–1.5 ka. Mayor (2005) focused on the use of fossils by Native Americans at the time of contact with western Europeans. Duffin (2008) as well as van der Geer and Dermitzakis (2008) reviewed the use of fossils in medicine. McNamara (2010) discussed the intentional inclusion of fossil sea urchins in graves dating from the Paleolithic era until at least the 12th century A.D. Most recently, Taylor and Rosenblum (2013) have developed a useful and comprehensive website on fossil folklore.

There are three criteria for determining if a fossil bryozoan was intentionally collected as an artifact versus simply as an incidental inclusion in an artifact or accidental incorporation into an archaeological site simply as a background fossil weathering out of a local outcrop. First, what is the geographic position of the archaeological site relative to the potential outcrops of the fossil? For example, are they separated by a drainage divide and/or distantly located as to be unlikely to end up in the archaeological site by natural geomorphic processes? Did it have to be intentionally transported from the outcrop source to the archaeological site where it was found? For example, Key et al. (2009) reported the internal mold of a fossil Miocene clam in a prehistoric Native American site in Virginia, USA, 20 km away from its outcrop source on the opposite side of a drainage divide. It had to have been purposely transported to the site.

Second, the context in which the bryozoan was found is important for determining whether it was an artifact itself or just incidentally co-occurring within an archaeological site. Was the fossil found in association with an archaeological feature (e.g., in a burial chamber) as opposed to scattered on the land surface from natural weathering processes or construction detritus? For example, Connolly (1996) and Wyse Jackson (1999) reported several loose, cleaned fossils that had been intentionally collected and placed in the primary chamber of a Neolithic megalithic passage tomb in Ballycarty, Ireland (Figure 1A and B). A passage tomb is a burial chamber connected to the surface by a horizontal narrow passage made of large stones covered in soil and stone (Connolly, 1999). The fossils included a bryozoan along with

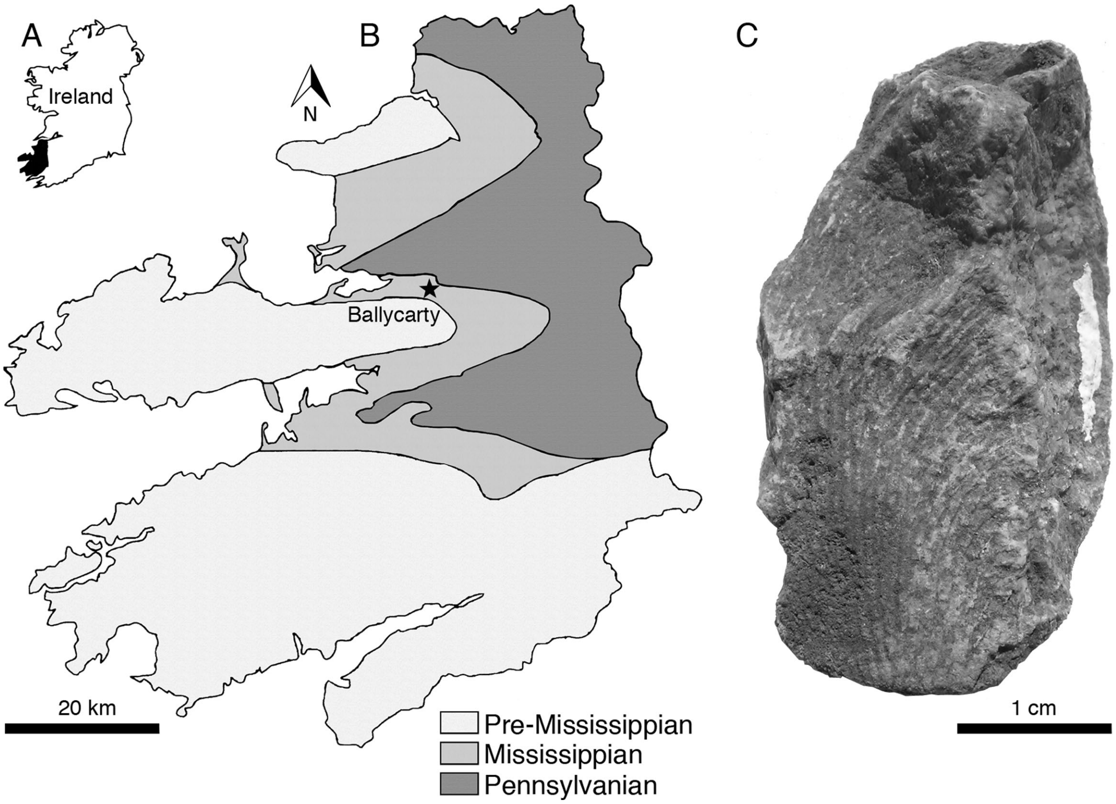

Figure 1 (A) Outline map of Ireland showing the location of County Kerry (in black). (B) Geologic map of County Kerry, indicating location (star) of the Ballycarty Neolithic passage tomb within the outcrop belt of Mississippian (Lower Carboniferous) limestone. (C) Photograph of the fenestellid fenestrate bryozoan *Fenestella s.l.* from the Lower Carboniferous (Mississippian) Waulsortian Limestone. It was found inside the burial chamber of the Neolithic passage tomb at Ballycarty. (A) and (B) modified from Wyse Jackson and Connolly (2002, Fig. 1); (C) Courtesy of the Kerry County Museum, Tralee, County Kerry, Ireland.

gastropods, cephalopods, and brachiopods (Wyse Jackson, 1999; Wyse Jackson & Connolly, 2002). We here illustrate and identify the bryozoan (Figure 1C) as the fenestellid fenestrate bryozoan *Fenestella*. There are four independent arguments that the fossil bryozoan was intentionally collected. One, it was discovered inside the burial chamber of the passage tomb, and as such it could not have become incorporated through natural erosion. Two, it was found on top of the clay floor of the chamber that covered the limestone bedrock, so it could not have become incorporated through natural erosion. Three, it was found with other intentionally placed artifacts (i.e., a perforated limestone bead, water-rounded quartz and red sandstone pebbles, charcoal, and cremated bones). Four, it had been extracted/collected as a loose fossil and had been cleaned (i.e., most of the surrounding matrix removed) before placement in the tomb (Connolly, 1999; Wyse Jackson, 1999; Wyse Jackson & Connolly, 2002).

Based on the regional geographic distribution of fenestrate bryozoan taxa (Wyse Jackson & Buttler, 1994; Wyse Jackson, 2006), it must have been collected from the underlying Mississippian (Lower Carboniferous) Waulsortian Limestone (Figure 1B), indicating a minimal transport distance (Table I). Based on its archaeological context, it must have been intentionally collected by the builders of the passage tomb and placed in it as a ceremonial decoration or charm (Connolly, 1996; Wyse Jackson & Connolly, 2002).

The third criterion for determining if a fossil bryozoan was intentionally collected as an artifact is whether the artifact was deliberately modified or shaped in any way by humans. For example, Oakley (1965: Figure 2) reported Eocene molluscs and brachiopods from an Upper Paleolithic site in Moravia that were perforated for hanging on a necklace, and Taylor and Robison (1976) reported a Cambrian trilobite drilled for use in a Native American necklace in Utah. The only examples of fossil bryozoans that were deliberately modified as artifacts are from the Harris archaeological site, a Late Pithouse period (550–1000 A.D.) Mogollon Culture occupation located in

Table I Summary table of archaeological sites discussed in this study.

	Ballycarty	Harris	Richard Stauffer	Cheetup
Site type	Passage tomb	Pithouse dwelling	Village	Rock shelter
Site location	County Kerry, Ireland	Mimbres Valley, New Mexico, USA	Morris County, Kansas, USA	Cape Le Grand National Park, Esperance, Western Australia
Site age	Neolithic	Late Pithouse	Archaic-Middle Ceramic	Mesolithic
Type of lithic artifact	Limestone fossil burial offering	Limestone fossil pendants	Chert projectile point	Chert flake
Bryozoan species	*Fenestella s.l.*	*Fenestella s.l.* and *Leioclema* sp.	*Rectifenestella tenax*	*Cellaria* sp.
Geologic source	Lower Carboniferous (Mississippian) Waulsortian Limestone	Lower Carboniferous (Mississippian) Lake Valley Formation	Lower Permian Wreford Limestone	Upper Eocene Wilson Bluff Limestone
Distance from source (km)	0	43	3	5

the Mimbres Valley of southwestern New Mexico, USA (Falvey, 2012; Falvey & McLaurin, 2012; Figure 2A). The excavations are in deposits that do not contain fossils, but 27 specimens of marine corals, crinoids, brachiopods, and bryozoans have been recovered from 14 of the 19 pithouses excavated thus far. A pithouse is a dwelling, partly dug into the ground, roofed over, and earthen covered (Haury, 1936, 1986). Several of the fossils were found below the floors of superimposed pithouses suggesting they may have been placed there before construction of the second house or may have been placed as offerings in the walls and roofs during construction. In addition, the fossils show evidence of cultural modification, suggesting they held symbolic value for the prehistoric inhabitants of the Harris Site and were intentionally collected.

A total of seven fossil bryozoan specimens were found at the Harris Site. Six were molds of thin decalcified fenestrate fronds ranging in length from 13 to 34 mm (mean: 18 mm, standard deviation: 7.4 mm) and in width from 10 to 20 mm (mean: 13 mm, standard deviation: 3.4 mm). One fenestrate bryozoan frond was drilled to make a pendant with intact peripheral edges of the pendant polished to shape (Figure 2B). The 14 × 10 × 5 mm pendant contains a single hole that is circular, with jagged sides as it penetrates the fossil. It is drilled from both sides (i.e., biconical) like other pendants from the same culture

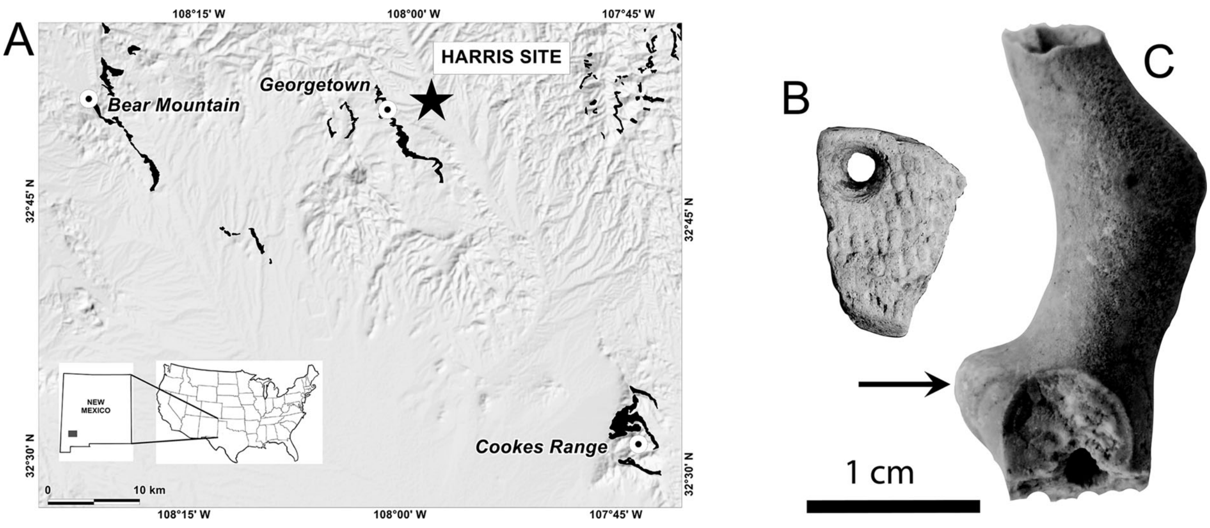

Figure 2 (A) Map showing location of Native American Harris Site (star) in New Mexico, USA, relative to outcrops of the Lower Carboniferous (Mississippian) Lake Valley Formation (in black). The Harris Site is a Late Pithouse period occupation located in the Mimbres Valley of southwest New Mexico. (B) Photograph of fenestellid fenestrate bryozoan *Fenestella s.l.* drilled for a pendant. (C) Photograph of leioclemid trepostome bryozoan *Leioclema* showing a new branch forming on the lower left side of the colony (arrow) that is polished smooth from human handling.

(e.g., Creel & Anyon's (2010: Figure 4.7) shell pendant). There are three independent pieces of evidence indicating the pendant was manufactured as the hole could not have been made by a natural borer. First, the authors have researched borings in bryozoans (Wyse Jackson & Key, 2007), and there are no records of natural borings in fenestrates as there is just not enough skeleton to bore through. Second, the boring is biconical, and there are no documented cases of biconical drilling by a nonhuman animal. Third and most telling, as the pendant is a mold of a decalcified frond, the pendant was made after the fond was fossilized. Otherwise the "boring" would have been in positive relief.

The ramose colony fragment was 28 mm long with a diameter of 8 mm. Toward the base of the fragment, a new branch that was forming on the side of the colony is polished smooth (Figure 2C). This has not been seen in branches of other ramose trepostome colonies, and microscopic use-wear analysis suggests the smoothness resulted from human handling.

The fossils appear to have had symbolic value to the occupants of the Harris Site and may have been used in household rituals. DeMaio (2010) as well as Roth and Schriever (2010) have shown that they were placed within the roof and walls during pithouse construction, probably as dedicatory objects. The Mogollon Culture is known for placing a variety of dedicatory objects in their buildings such as turquoise, calcite, and quartz crystals, as well as shell beads and bracelets (Creel & Anyon, 2010).

The most likely sources of the fossil bryozoans found in the Harris Site are the regionally outcropping Devonian Percha Shale or the Lower Carboniferous (Mississippian) Lake Valley Formation as both have diverse bryozoan faunas (Fritz, 1944; Laudon & Bowsher, 1949; Pray, 1958; O'Neill et al., 2002). Determining from which geologic unit the specimens were collected required taxonomic identification of the bryozoans. The fenestrate pendant is moldic, and no skeletal material remains. This makes identification to even the genus level difficult. However the gross shape and size of branches and fenestrules do not match those of the fenestellids described from the local Devonian Percha Shale (Fritz, 1944). Fenestellid fenestrate bryozoans, including *Fenestella*, have been reported as being diagnostic of the local Andrecito Member of the Lake Valley Formation (Laudon & Bowsher, 1949), which was deposited during the Tournaisian stage of the Lower Carboniferous (Early Mississippian) Period (Armstrong & Mamet, 1978). Kues (1986) lists 13 bryozoan taxa from the Lake Valley Formation including the fenestellids *Fenestella* and *Polypora*. The squat rectangular form of the fenestrules and the narrow branches suggest that the fenestellid is a species belonging to *Fenestella s.l.* and not *Polypora s.l.*, as one might expect more elongate fenestrules and thicker branches where they belong to the latter.

The ramose colony was badly weathered, poorly preserved due to severe recrystallization, and the endozone was bored out (*sensu* Wyse Jackson & Key, 2007). This makes identification to even the genus level difficult, especially since a thin-section of the artifact could not be produced. However based on gross morphology and species lists from previous studies, the ramose colony was tentatively identified as the leioclemid trepostome bryozoan *Leioclema* that was reported by Kues (1986) from the Andrecito Member of the Lake Valley Formation. Thus based on the occurrence of these two genera, we hypothesize that the bryozoans came from the Lake Valley Formation as it contains numerous bryozoan-rich limestones (Laudon & Bowshwer, 1949; Kues, 1986; O'Neill et al., 2002), including some formed by fenestrate-constructed bioherms (Pray, 1958).

The closest possible bryozoan-bearing outcrops of the Lake Valley Formation are near Georgetown, New Mexico (4 km west of the Harris Site, Figure 2A). Further outcrops can be found as far west as Bear Mountain (33 km west of the Harris Site) and as far south as Cookes Peak (43 km southeast of the Harris Site, Figure 2A). Despite being the farthest away, Cookes Peak is the most likely source as the outcrops there contain abundant bryozoans (Laudon & Bowsher, 1949; Jicha, 1954) and archaeological evidence suggests Cookes Peak held ideological significance for the prehistoric inhabitants of the Mimbres Valley. Cookes Peak is a distinctive feature of the landscape and visible from the Harris Site. Residential and ceremonial structures throughout the Mimbres Valley are typically oriented with their entrance ways facing Cookes Peak (Ruzicka, 2010). Petroglyphs at the base of the mountain suggest ceremonial rituals took place there. Fossils from the outcrops at Cookes Peak may have been collected as mementos of participation in the ceremonies and brought back to the Harris Site (Falvey & McLaurin, 2012). The fossils must have had great value as only 1–3% of Late Pithouse period Mimbres Mogollon lithic artifacts come from a >20 km radius (Schriever, Taliaferro, & Roth, 2011).

There are numerous reasons why prehistoric peoples collected fossils (Oakley, 1965; Wyse Jackson & Connolly, 2002; Taylor & Rosenblum, 2013). First, they may have been collected for curiosity's sake, which eventually evolved into natural history collections and modern science. These kinds of artifacts are a type of curio. Second, a distinctive fossil may have spiritual/metaphysical significance or religious value (e.g., the trepostome fragment from the Harris pithouse). An object intended to bring good luck or protection to its owner is often referred to as a lucky charm, an amulet, or talisman. Third, they may have been collected for aesthetic reasons to use in ornamentation (e.g., the fenestrate frond from the Harris pithouse). For example, Lane and Ausich (2001) documented the use of Carboniferous crinoid columnals in making St Cuthbert's Beads in Britain. Bilaterally symmetrical fossils (e.g., shark teeth) are more commonly reported as prehistoric artifacts than nonbilaterally symmetrical fossils such as bryozoans (Oakley, 1965; Mayor, 2000, 2007; Taylor & Rosenblum, 2013). Is that a bias of the prehistoric collectors themselves or the archaeologists who may not have recognized nonbilaterally symmetrical fossils as organic remains?

BRYOZOANS AS INCIDENTAL ARTIFACTS

By incidental, we mean the presence of the bryozoan was not the reason the artifact was selected or manufactured. It is even possible that the bryozoan was not even apparent to the person that selected the object for use. There are only a few reports in the literature of incidental associations of fossil bryozoans on or in prehistoric artifacts that have not been used to source the artifacts. There are Lower Paleolithic/Bronze Age beads from England that are made of Cretaceous sponges that were fouled by bryozoans when the host sponges were alive (Oakley, 1978; Bednarik, 2005). Another example is that of a Late Mesolithic sculpture made from an Ordovician bivalve steinkern, which in itself, was fouled by bryozoans (Glørstad, Nakrem, & Tørhaug, 2004). Fossil bryozoans have been repeatedly reported as a tempering agent in prehistoric pottery (Carrott et al., 1995). Early Iron Age (750–550 B.C.) pottery from Studienka, Slovakia, was found to contain fossil bryozoan fragments from the Lower Badenian (Middle Miocene) Studenienske Formation (Gregor, Čambal, & Harmadyová, 2008). Fossil bryozoan fragments have also been reported in Iron Age pottery from England (Vince, 2004).

Published reports of incidental associations of extant bryozoans on or in prehistoric artifacts are more common. Monod and d'Hondt (1978) reported an extant marine bryozoan found in a 7500 B.C. shell midden at a Neolithic archaeological site in Mauritania. The membraniporid cheilostome bryozoan, *Biflustra commensale*, had constructed an involute helicospiral tube on a gastropod shell occupied by a hermit crab (*sensu* Taylor, 1994). It presumably was picked up along the northwest African coast and transported to the inland site south of Nouakchott, Mauritania (Monod & d'Hondt, 1978), probably due to the presence of the enclosed hermit crab, not the bryozoan. Fedje and Josenhans (2000) reported a 9.2 ka stone tool from British Columbia, Canada, that was discovered below sea level and encrusted by extant marine bryozoans. Bivalve shells that were fouled by bryozoans and collected as a food source have been reported from Roman shellfish dumps in England (Milles, 1995), Pictish shell middens in Scotland (Ritchie, 1977), and Bronze to Roman aged middens in France (Lefebvre et al., 2014). Neolithic pottery from Flevoland, The Netherlands, was found to be encrusted with bryozoans (Anscher, 2012). A slightly younger example is the Roman age amphorae that have been recovered from the Adriatic Sea and are encrusted by modern bryozoans (Sondi & Slovenec, 2003). Braga and Stefanon (1969) found the extant electrid cheilostome bryozoan *Conopeum seurati* and the schizoporellid cheilostome bryozoan *Schizoporella errata* encrusting a Roman amphora in the Venetian Lagoon, Italy.

Despite often being incidental, the occurrence of bryozoans in or on lithic artifacts can assist in sourcing or addressing other archaeological questions. Reverter-Gil et al. (2013) were able to trace a stolen Roman amphora to the Strait of Gibraltar based on its extant encrusting bryozoan fauna. Extant bryozoans encrusting sunken ships have even been used to constrain the ship's exposure time on the sea floor. This approach has been applied to 3rd century B.C. (Tusa & Royal, 2012) as well as 18th (Hageman, 2001), 19th (Cuffey & Fonda, 1982, 1983), and 20th century A.D. shipwrecks (Cuffey, 2000). Subfossil bryozoans were used to constrain the geographic setting of an Iron Age site near Delfzijl, The Netherlands (Hielkema, 2012). The electrid cheilostome *Einhornia crustulenta* was found encrusting a piece of pottery at the site. As this species is a brackish estuarine species, its presence was used to suggest a coastal setting for the archaeological site. Unfortunately such incidental bryozoans are often removed from the artifacts during the curation process. For example, a Native American flint drill recovered on a Gulf of Mexico beach in Texas, USA, was originally fouled by extant bryozoans, but the bryozoans were subsequently "cleaned off" during preparation of the artifact (Stright, Lear, & Bennett, 1999).

USE OF INCIDENTAL FOSSIL BRYOZOANS IN SOURCING PREHISTORIC LITHIC ARTIFACTS

Though a fossil bryozoan may have been incidental in a lithic artifact, it can still be useful for sourcing the artifact. The oldest fossil bryozoans reported in prehistoric lithic artifacts are in the flints from the Lower Carboniferous (Mississippian, Chesterian) Bangor Limestone of northern Alabama, USA. The diverse bryozoan fauna of the Bangor Limestone is dominated by non-fenestrates (McKinney, 1972). This lithology was commonly

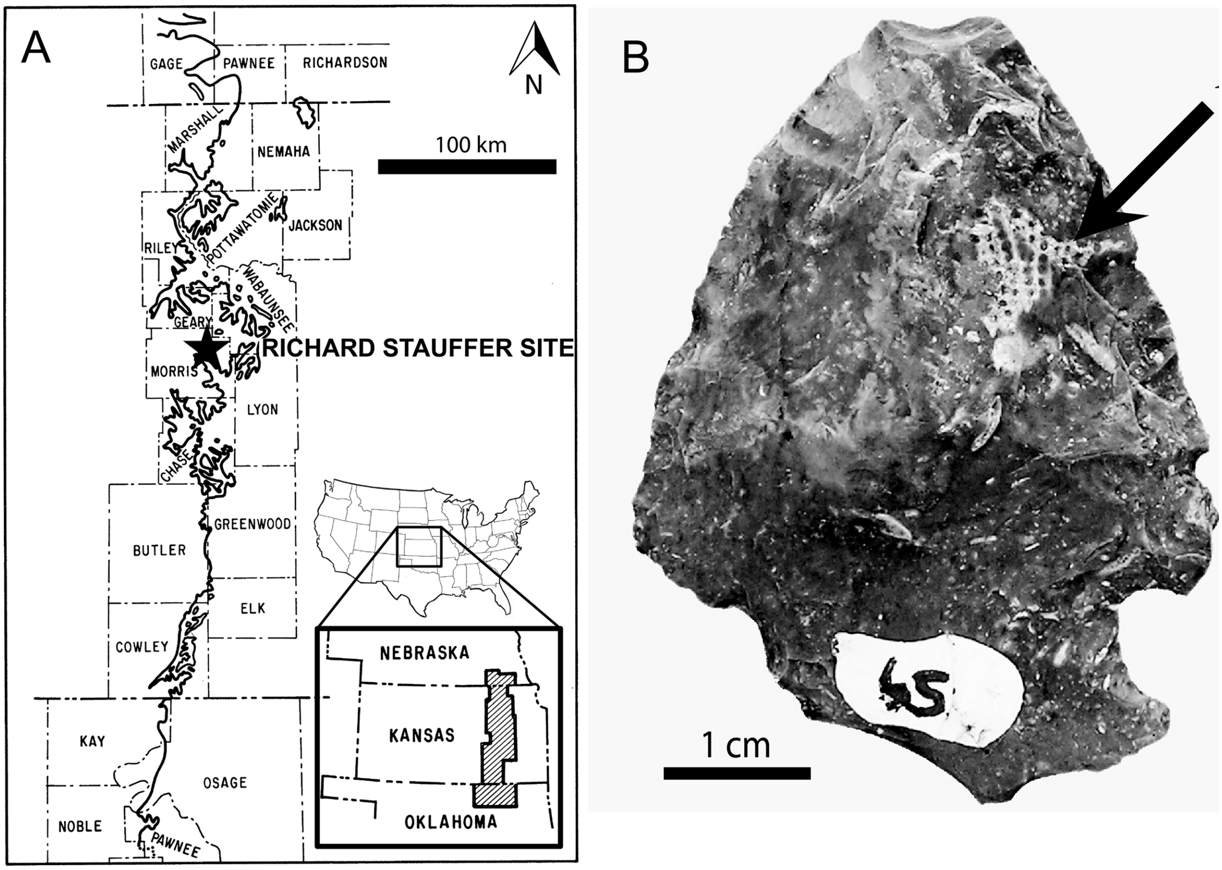

Figure 3 (A) Map showing the location of the Archaic-Middle Ceramic Richard Stauffer Site (star) relative to the Wreford Limestone outcrop belt in the Flint Hills of Nebraska, Kansas, and Oklahoma, USA. Modified from Newton (1971: Figure 2). (B) Photograph of Native American projectile point SS39 containing a colony fragment (arrow) of the fenestellid fenestrate bryozoan *Rectifenestella tenax*. Provided by Donald Blakeslee (Wichita State University).

exploited by Native Americans 5.7–5.3 ka from northwestern Alabama (Meeks, 2000) to southern Alabama (Potts & Carr, 2011). The presence of bryozoan fossils is a key diagnostic property of Bangor flint used to determine the source rock for the lithic artifacts (Meeks, 2000; Potts & Carr, 2011).

The Flint Hills of central Kansas, USA, have long been known for their Middle Archaic to Early Ceramic period (6.2–0.7 ka) Native American artifacts (Wedel, 1959). To the archaeologists working on lithic artifacts from the surrounding area, gray flints are indicative of the Permian limestones from the Flint Hills region, several members of which yield gray cherts (Blakeslee, personal communication, 2011). The Threemile Limestone Member of the Wreford Limestone Formation and the Florence Limestone Member of the Barneston Limestone Formation, both of the Lower Permian Chase Group, yield diagnostic bryozoan-bearing cherts commonly used by local Native Americans (Haury, 1979, 1984; McLean, 1998). Additionally, numerous Native American chert quarries have been mapped in these limestones (Stein, 2006). The embedded fragmented bryozoans in the lithic artifacts support this paleobiogeographic assignment. For example, projectile point SS39 from the Stauffer-Allison Collection was recovered from the Richard Stauffer Site (14MO407) in Morris County, Kansas, USA (Figure 3A). This Native American artifact is from an Archaic to Middle Ceramic village site above the Bluff Creek flood plain. It contains a colony fragment of a fenestellid fenestrate bryozoan (Figure 3B). Based on comparison morphometric data from Simonsen and Cuffey (1980: Table 2), the dimensions of its fenestrules, branch parameters, and number of zooecial apertures per fenestrule, we identified it as the Lower Carboniferous to Lower Permian bryozoan *Rectifenestella tenax* (Ulrich, 1888). This species has been reported from the Flint Hills region of central Kansas, where it is common in the cherty units of the Lower Permian Wreford Limestone of the Chase Group (Simonsen & Cuffey, 1980) where point SS39 was found, indicating a minimum transport distance of 3 km (Table I).

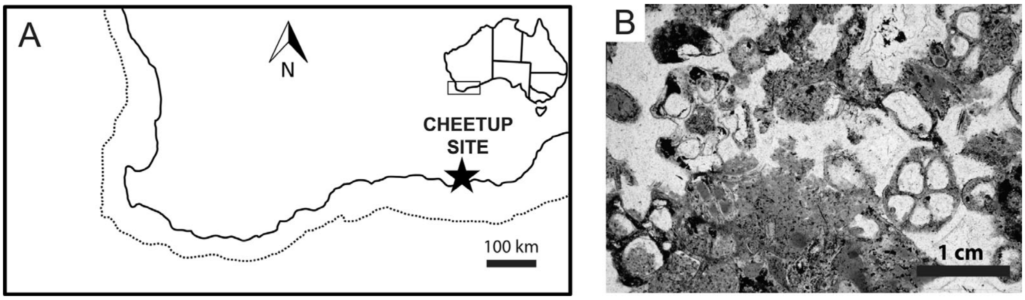

Figure 4 (A) Map showing location of the Cheetup rock shelter (star) in Western Australia. The dashed line indicates the maximum extent of emergent continental shelf at the last glacial maximum. Modified from Dortch and Smith (2001: Figure 1). (B) Photomicrograph showing four transverse sections of the cellariid cheilostome bryozoan *Cellaria* from Aboriginal artifact number 69, a flint flake found 25 cm below the surface in trench F12 dated to 8–13 ka. Provided by John Glover (University of Western Australia) and Moya Smith (Western Australia Museum), courtesy of the Western Australian Museum.

In southeastern Iowa, western Illinois, and northeastern Missouri, USA, several Lower Carboniferous (Lower to Middle Mississippian, Kinderhookian to Meramecian stages) bryozoan-rich limestones outcrop. These contain bryozoan-rich cherts from the Chouteau, Burlington-Keokuk, and Warsaw Limestones that were often used for Paleoindian to Middle Woodland (13–1.1 ka) points and knives (Morrow, 1983, 1984, 1994; Ray, 1983, 2007; McLean, 1998; Morrow & Morrow, 2004). The fenestrate and ramose fossil bryozoans are so diagnostic of the various cherts (Burlington and Keokuk, respectively) that the State Archaeologist of Iowa has created on online binary identification key that uses fossil bryozoans for sourcing them (Morrow, 1994; Morrow & Morrow, 2004).

The youngest fossil bryozoans found in prehistoric lithic artifacts are those from the Eocene in the Aboriginal lithic artifacts from the Perth Basin in southwestern Western Australia (Glover, 1984; Dortch & McArthur, 1985). The most notable lithic artifacts for their size are the 16.5-cm-long Cope Cope flake (Massola, 1969) and the 18.1-cm-long Broke Inlet biface (Glover, Bint, & Dortch, 1993). These artifacts have been dated to 11–25 ka (Dortch & Merrilees, 1973; Dortch, 1986). They typically are made of chert containing identifiable bryozoan colony fragments, from which 14 species have been identified by Glover and Cockbain (1971). The bryozoans in these lithic artifacts have been used to determine the source of these flints as the Middle to Upper Eocene silicified bryozoan limestones west of the archaeological sites (Quilty, 1978; Glover, 1984; Glover, Bint, & Dortch, 1993; Smith, 1993). Interestingly, the outcrops are currently submerged below sea level, but they were exposed to Aboriginal quarrying 6–25 ka (Figure 4A), before succumbing to the rising sea level of the last deglaciation (Quilty, 1978; Glover, 1975a, 1975b, 1984; Glover, Bint, & Dortch, 1993). Glover, Bint, and Dortch (1993: Figure 3) illustrated a transverse thin section of a bryozoan from the Broke Inlet biface that we identified as a 15th species, the entalophorid cyclostome *Entalophora*. Further east from the 8–13 ka Cheetup rock shelter (Smith, 1999), we identified the cellariid cheilostome bryozoan *Cellaria* in a chert flake (Figure 4B). This last species is most likely from the bryozoan marl facies of the onshore Upper Eocene Wilson Bluff Limestone of the Eucla Basin, indicating a minimum transport distance of 5 km (Table I). The Wilson Bluff Limestone, with its abundant bryozoans and siliceous sponge spicules, is the probable source as it would have easily diagenetically altered into a bryozoan-rich chert (Gammon & James, 2003).

DISCUSSION AND CONCLUSIONS

Despite the potential for using fossil bryozoans to source archaeological artifacts, the previous case studies reveal three drawbacks of using fossil bryozoans for sourcing artifacts. First, many of the bryozoans in prehistoric lithic artifacts are preserved in flint. Flint is the result of a diagenetic process involving silicification where the original carbonate is replaced by amorphous quartz. Delicate bryozoan colonies do not often survive this process due to their high surface-area-to-volume ratio (Madsen & Stemmerik, 2010). Second, the stratigraphic and geographic distributions of fossil bryozoans are incompletely known. Many more faunas need to be described globally. Third, fossil bryozoans tend to need to be thin-sectioned for proper identification. Bryozoans often fragment easily (e.g., Smith, 1995), which can make them small enough to be found in small artifacts and dimension stones, like a microfossil (Key & Wyse Jackson, 2014). But these small fragments typically require thin-sectioning for taxonomic identification. Geoarchaeologists have to balance the benefits of determining the source of the artifact with the cost of the destructive process of thin-sectioning.

Fossil bryozoans from throughout their stratigraphic range (Ordovician to the Neogene) can be found in prehistoric artifacts. Although we found examples of bryozoans in artifacts from four different orders (i.e., trepostomes, fenestrates, cyclostomes, and cheilostomes), we failed to find any examples from the other orders (i.e., cryptostomes, cystoporates, and ctenostomes). Other than a probable taphonomic bias against the nonmineralized ctenostomes, the other orders should be found in lithic artifacts. Their absence in this study is more likely simply a function of our small sample size.

Although most fossil bryozoans are incidental in these artifacts, the bryozoans are still useful for determining their source. Improved searchable online paleontologic databases allow for more efficient use of fossil bryozoans to constrain the stratigraphic and paleogeographic distribution of source rocks. Despite underutilization in provenance studies of prehistoric artifacts, it is clear that if more attention was paid to bryozoans, an increased understanding of the lithologic nature of these materials could be gained by the archaeological community. Sourcing lithic material in geoarchaeological studies is a very active area of research incorporating a wide range of approaches (e.g., Pavia, Marsaglia, & Fitzpatrick, 2013). Some lithic sources are more challenging to source. For example, sourcing chert is not always straightforward (e.g., Parish, Swihart, & Li, 2013), and the new methods described here will hopefully provide new insights.

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